Minnesota Depressional Wetland Quality Assessment: Survey Design Summary (2007-2009)

November 2007

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Introduction

The Comprehensive Wetland Assessment, Monitoring and Mapping Strategy (CWAMMS Steering Committee 2006) outlined the necessary activities for achieving a scientifically sound strategy for monitoring and assessing wetland quantity and quality in Minnesota. A major component of this strategy is a statewide probabilistic survey of wetland quantity and quality based on randomly selected 1 mi^2 plots or primary sampling units (PSUs). The purpose of this document is to summarize the sampling design for the initial 3-year cycle of the wetland quality survey.

Indicators are used to assess the quality of wetlands. The quality of a wetland can be measured in two different ways: 1) by examining its deviation from least-impacted reference condition (condition assessment) and 2) by estimating the goods and services it provides (functional assessment). The two approaches are complimentary (Stevenson and Hauer 2002) and together provide a thorough assessment of overall wetland quality. Currently, the Minnesota Pollution Control Agency (MPCA) only has condition indicators developed for depressional wetlands with predominantly emergent marsh vegetation. As such, the first 3-year cycle of the wetland quality survey will focus on this particular class of wetlands with the expectation that other wetland types will be included in subsequent cycles of the survey as condition indicators for these are developed. Plant and macroinvertebrate indices of biological integrity (IBIs) have been developed independently and calibrated according to Omernick Level II ecoregions (Omernick 1987) to assess the condition of depressional wetlands statewide (Gernes and Helgen 2002, Genet and Bourdaghs 2006, Genet and Bourdaghs 2007). The Minnesota Routine Assessment Method (MnRAM) is a wetland functions and values assessment that is applicable to all wetland types (MN BWSR 2007); however, in the initial cycle of the statewide survey only emergent depressional wetlands will be assessed using MnRAM version 3.1 to match the scope of the IBI condition assessments.

In addition to the overall functional and condition assessments, a number of individual water chemistry parameters will be measured and used to estimate conditions statewide. These parameters provide valuable information regarding the types of anthropogenic stressors impacting wetland quality. For a complete list of indicators and parameters see Table 1.

Wetland Quantity Survey

The basis for generating the wetland quality survey sample is the wetland map created by the photointerpretation of high-resolution true-color imagery for each of the randomly selected 1 mi^2 PSUs. Therefore, in order to fully understand the quality design, a brief introduction must first be provided for the wetland quantity survey. The quantity survey was designed to estimate status and detect trends in the quantity of Minnesota's wetlands (all types) using a cyclical, interpenetrating panel sample design utilizing the Generalized Random Tessellation Stratified (GRTS) (Stevens and Olsen 2004) technique to ensure spatial balance of the randomly selected PSUs across the state. This interpenetrating panel design partitions the overall sample among three distinct panels and each panel consists of a spatially balanced sample of PSUs across the entire state. Each panel is then sampled (i.e., aerial imagery obtained for the PSUs, photointerpretation, etc.) every three years. A total of 1,830 plots will be selected in each panel,

Table 1. Assessments and parameters included in depressional wetland quality assessment (2007-2009).

Condition Assessments:	Water Chemistry Parameters:
Plant IBI	Chloride (mg/L)
Macroinvertebrate IBI	Color (PCU)
	Conductivity (*u* S/cm)
Functional Assessments (MnRAM 3.1):	Dissolved Oxygen (mg/L)
Vegetative Diversity/Integrity	Kjeldahl Nitrogen (mg/L)
Hydrology - Characteristic	Nitrite + Nitrate Nitrogen (mg/L)
Flood Attenuation	pH
Water Quality--Downstream	Phosphorus (mg/L)
Water Quality--Wetland	Sulfate (mg/L)
Shoreline Protection	Temperature (^{o}C)
Characteristic Wildlife Habitat Structure	Total Organic Carbon (mg/L)
Maintenance of Characteristic Fish Habitat	Transparency (cm)
Maintenance of Characteristic Amphibian Habitat	Turbidity (NTU)
Aesthetics/Recreation/Education/Cultural	
Commercial use	

Table 2. First two iterations of CWAMMS wetland quantity design.

Panel	2006	2007	2008	2009	2010	2011
Annual	250	250	250	250	250	250
Panel 1	1580			1580		
Panel 2		1580			1580	
Panel 3			1580			1580
Total	1830	1830	1830	1830	1830	1830

with 250 of these being repeated every year ("Annual") and 1,580 of these being unique to each panel ("Panels 1-3") and repeated every three years (Table 2). This design focuses on (1) annual extent estimates based on 1830 plots each year, (2) annual change in extent estimates based on 250 plots, (3) 3-year extent estimates based on 4990 plots, (4) 3-year gross change in extent estimates based on 4990 plots, and (5) trends over time. Repeat sampling of plots, whether on a 1- or 3-year schedule, will allow this design to detect gross change (e.g., tracking acreage in plots through time). Gross change provides estimates of changes among classes (e.g., Table 3 and upland classes) going from any one class to any other class.

Wetland Quality Survey

The target population for the first cycle of the wetland quality survey is depressional wetlands with a predominantly emergent marsh plant community and a water regime ranging from semi-permanent to permanently flooded. Depressional wetlands could either be isolated (no discernable outlets), flow-through (apparent inlet and outlet), or tributary (outlet but no perennial inlet) systems. Patterns of emergent vegetation within target wetlands range from complete coverage to total absence (which can occur in severely degraded wetlands). Waterbodies with artificially maintained water levels such as wastewater treatment ponds, aquaculture impoundments, and cranberry ponds will not be considered part of the target population.

Due to inaccuracies of the existing National Wetlands Inventory (NWI; Cowardin et al. 1979) and the cost of updating this data set statewide, it will not be feasible to use this inventory as a sample frame for the wetland quality survey. Therefore, a two-phase sampling approach (Särndal et al. 1992) will be utilized to compensate for the lack of a complete wetland sample frame (Stevens and Jensen 2007). For this wetland quality survey, the phase 1 sample will be derived from the randomly selected 1 mi^2 PSUs. The phase 2 sample is a randomly selected subset of the phase 1 sample. This arrangement closely resembles the two-tiered design originally proposed by Wetlands-EMAP (Leibowitz et al. 1991, Novitzki 1995). Phase 1 of the design uses a GRTS survey design for an areal resource, while phase 2 uses a GRTS survey design for discrete objects. The discrete objects in phase 2 are individual polygons and their location is identified by their centroid. Both GRTS designs include reverse hierarchical ordering of the selected sites.

Phase 1 Sample

The phase 1 sample for the wetland quality survey will be all of the photointerpretted wetland area within the 4990 (250 Annual + 3*1580 Panel) randomly selected 1 mi^2 PSUs. Although for the first 3-year cycle of the survey, the phase 1 sample will be derived from photointerpretation of imagery obtained in spring of 2006 for the 250 Annual and 1580 Panel 1 PSUs. In addition, the resulting wetland maps will need to be modified based on further photointerpretation in order to better approximate the target population of depressional wetlands. Emergent (inundated), aquatic bed, and unconsolidated bottom wetland classes (Table 3) occurring within a depressional hydrogeomorphic (HGM) setting will be selected to represent the target population and included in the phase 1 sample. When only a portion of the target wetland occurs within the

Table 3. CWAMMS Wetland classes (modified from Cowardin et al. 1979).

Class[1]	Water Regime	Description
Forested	--	Wetland dominated (>30% cover) by trees or shrubs over 6 m (20') tall.
Scrub-Shrub	--	Wetland dominated (>30% cover) by woody vegetation under 6 m (20') tall and typically having multiple stems.
Aquatic Bed	--	Water habitat dominated by plants growing below or floating on the surface most of the growing season.
Unconsolidated Bottom	--	Water habitat less than 2 m (6.6') deep and with less than 30% plant cover.
Cultivated	--	Water or ineffectively drained wetland in fields under cultivation, where hydrophytes would reestablish if farming were discontinued.
Emergent	Saturated Temporary Seasonal Inundated	Wetland dominated (>30% cover) by erect, rooted herbaceous plants emerging above surface water most of the growing season.

[1] A modifier can be added to the aquatic bed, unconsolidated bottom, and emergent wetland classes to denote that the wetland appears to have been manmade.

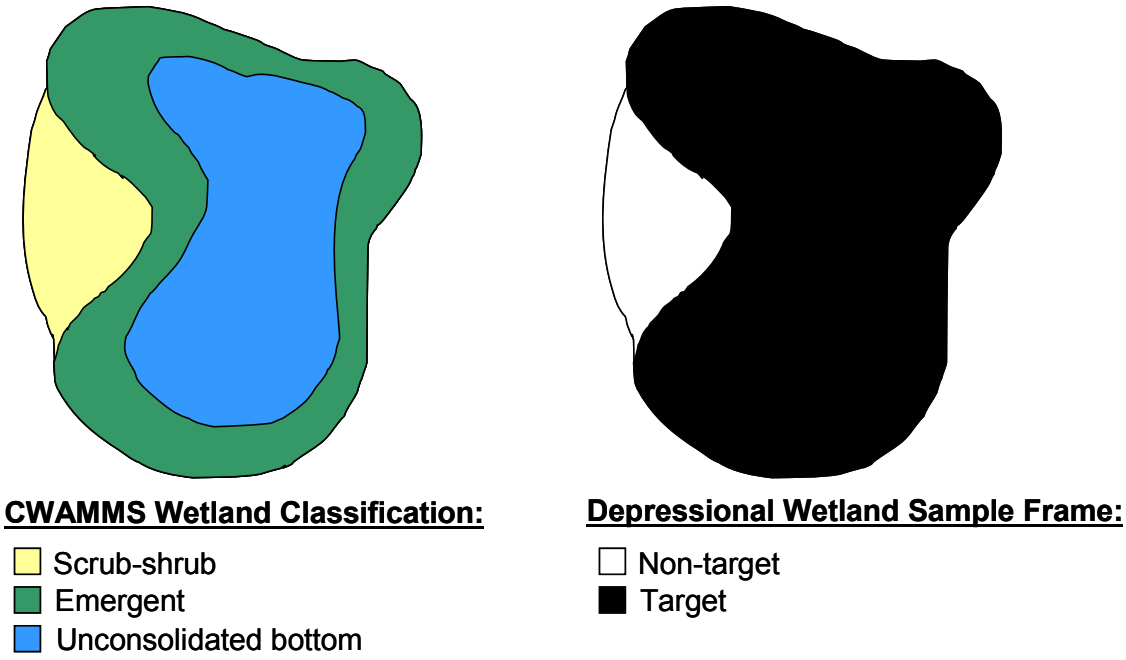

Figure 1. Relationship between CWAMMS wetland classification and depressional wetland sample frame. In the right hand illustration the black polygon represents the extent of the assessment unit; non-target wetland classes are omitted from the sample frame.

PSU, the remainder of the target wetland occurring outside of the PSU will be delineated in ArcMap™ using 2006 aerial photography and incorporated into the phase 1 sample. However, the final phase 1 sample for the depressional wetland survey will only include polygons whose centroid is within the boundaries of the randomly selected PSUs. Each polygon within this sample corresponds to the extent of target wetland classes within a depressional wetland basin, representing the assessment unit of this survey (Figure 1).

Phase 2 Sample

The final phase 1 sample of wetland polygons represents the frame for the phase 2 sample. The second phase consists of randomly selecting individual depressional wetlands from the phase 1 sample independent of PSU association (i.e., more than one wetland can be selected from a PSU). An overview of the entire two-phase sampling process and the relationship with the 1 mi^2 PSUs is illustrated in Figure 2. Weighting by wetland area will be incorporated into the phase 2 selection process as preliminary data indicate that greater than 75% of the target population is less than 1 ha in size. Wetland area categories will be as follows: < 1 hectare, 1 - 5 hectares, and > 5 hectares. Weights will be derived for these categories to increase the likelihood that an equal number of wetlands will be selected in each area class.

The depressional wetland quality survey design will follow a rotating schedule based on Omernick Level II ecoregions within the state (Figure 3), beginning in 2007 with the Mixed Wood Plains ecoregion. Therefore, only Panel 1 PSUs occurring within or intersecting the

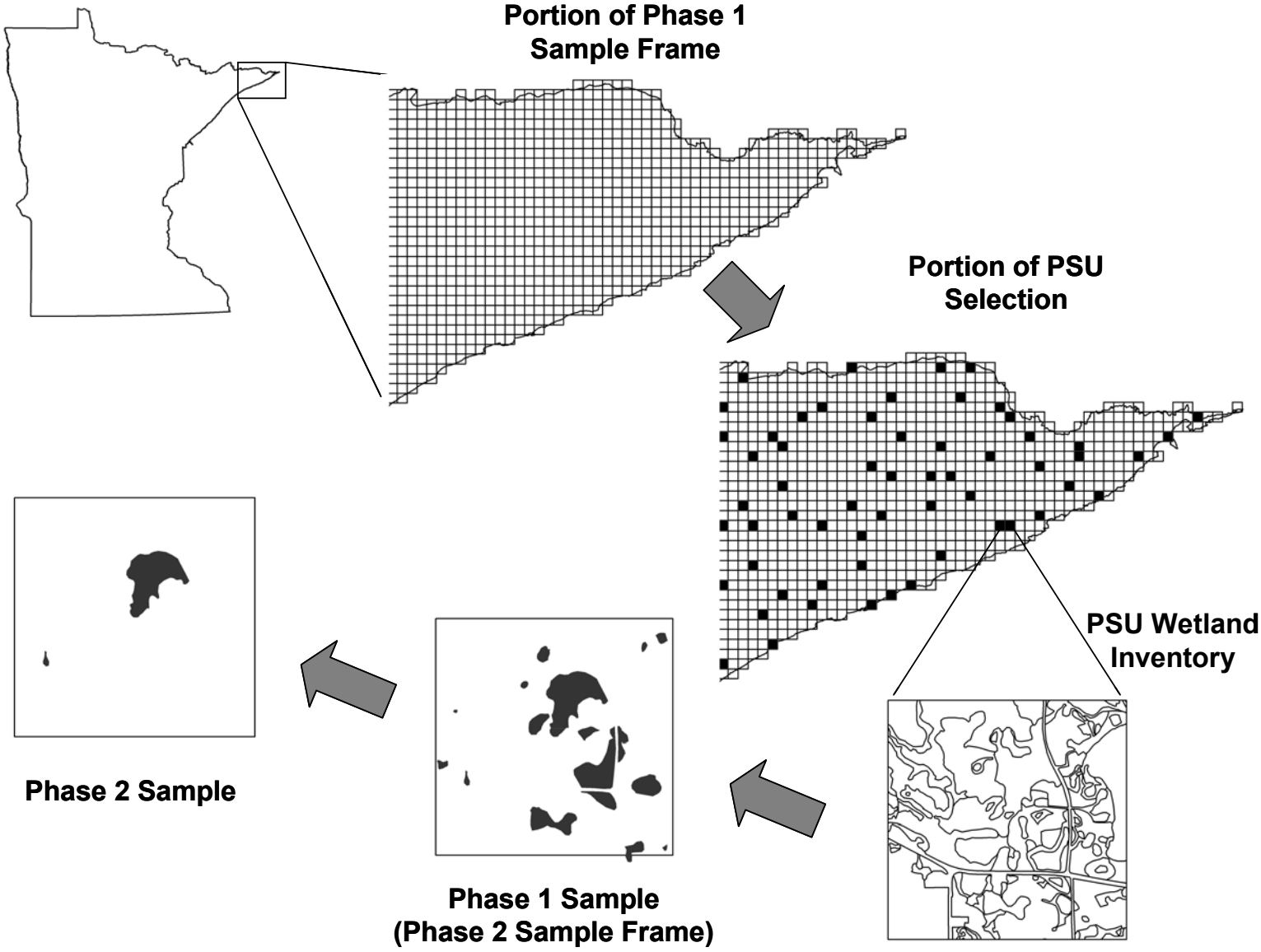

Figure 2. Two-phase sample design layout for the depressional wetland quality survey (2007-2009).

Table 4. Rotating ecoregion schedule of the depressional wetland quality survey.

Ecoregion	Year	Panel 1 PSUs[1]	Phase 2 Sample (# wetlands)
Mixed Wood Plains	2007	390	60
Temperate Prairies	2008	573	60
Mixed Wood Shield	2009	641	60

[1] Total does not sum to 1580 (Total # of Panel 1 PSUs) because PSUs that overlap ecoregions are included in the total of each.

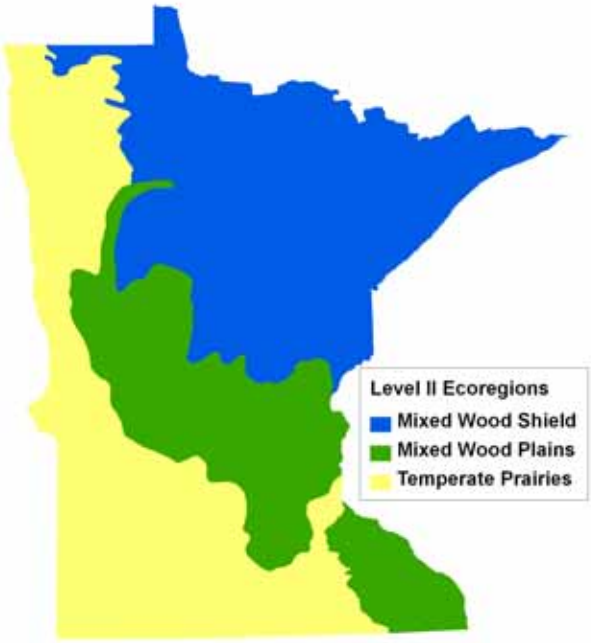

Figure 3. Geographic framework for rotating ecoregion schedule of emergent depressional wetland quality survey.

border of this ecoregion will be used to generate the phase 1 sample. Individual wetland polygons that occur on the ecoregion border will be included within the ecoregion that contains the majority of their area. The schedule, number of PSUs in each ecoregion, and anticipated phase 2 sample sizes are listed in Table 4. This design will facilitate the achievement of the following monitoring objectives: (1) estimate emergent depressional wetland function and condition for an individual ecoregion based on 60 sites each year, (2) estimate emergent depressional wetland function and condition statewide based on 180 sites over three years, (3) determine 3-year net change in wetland function and condition both statewide and for individual ecoregions, and (4) detect long-term trends in wetland function and condition over time.

In addition to the rotating ecoregion design, a separate two-phase sampling approach was utilized to randomly select depressional wetlands from the Annual PSUs. Similar to the intended function of the Annual PSUs in the wetland quantity survey, these sites will be sampled each year to characterize annual variability. A total of three sites in each ecoregion, one in each wetland area category, will be used to assess whether any large-scale climatic effects (e.g., drought) are influencing the condition of the sample sites (and thus the entire population of depressional wetlands in an ecoregion) in any given year of the quality survey.

Site Evaluation

In both designs (rotating ecoregion & annual), the phase 2 sample selection will include more sites than needed, in anticipation that some of the sites may not be accessible (e.g., landowner denial) or may not fit the criteria of the target population (e.g., non-target). Sites within the phase 2 sample selection are listed according to their site identification number and must be evaluated in this order. All sites that occur prior to the last site used in phase 2 sample must be evaluated for use and then either sampled or the reason documented why that site was not used. This is necessary because the weights used in the original survey design assume that the survey is implemented as designed. However, when a site can not be sampled and has to be replaced with the next site on the list in order to achieve the intended sample size of the original design this assumption is violated. When sites are replaced, the survey design weights are no longer

correct and must be adjusted. The weight adjustment requires knowing what happened to each site in the base design and the over sample sites. Therefore, all sites in the phase 2 sample selection will be categorized according to the evaluation status codes in Table 5.

Table 5. Site evaluation categories for the probabilistic depressional wetland quality survey (2007-2009).

Evaluation Status Code	Name	Description
TS	Target Sampled	Site is a member of the target population and was sampled.
NT	Non-Target	Site is not a member of the target population.
LD	Landowner Denial	Landowner denied access to the site.
PB	Physical Barrier	Physical barrier prevented access to the site.
NN	Not Needed	Site is a member of the over sample and was not evaluated for sampling.

In addition to the evaluation process required to properly adjust the survey design weights, a separate categorization process for each site in the phase 2 sample will be needed to classify waterbodies according to their regulatory status. It is the intention of the quality survey to measure wetlands that are considered waters of the state (State of Minnesota 2007) which can briefly be defined here as any wetland not being used as a treatment system operated under permit or certificate of compliance. Throughout Minnesota there are many manmade waterbodies that can resemble wetlands, but were not created with the intention of providing wetland habitat, as well as highly altered wetlands that have been legally mitigated for (MPCA 2005). In most cases, such waterbodies are not considered waters of the state. Alternatively; created, restored, and managed wetlands that clearly were manipulated for the purpose providing wetland area (and thus are waters of the state) also occur throughout the state and share many of the same features (e.g., linear shore lines, predominance of shallow open water). Aerial photointerpretation can not reliably distinguish these manmade wetland habitats from other manmade or highly altered waterbodies and thus can not ascertain the regulatory status of individual waterbodies. Even when visited on the ground, determining whether a particular waterbody is a water of the state can be a difficult task. Therefore, in order to analyze results from the wetland quality survey both with and without data from sites that are questionable waters of the state, the phase 2 sample will be post-stratified. Comparison of these two analyses will illustrate the contribution of the manmade waterbodies (e.g., ponds) to the overall condition of depressional wetlands. This will be particularly insightful if the wetland quantity survey demonstrates a decrease in natural emergent depressional wetlands accompanied by an increase in manmade open water habitats, similar to the trend observed at the national scale (Dahl 2006).

Three categories will be used to post-stratify the phase 2 sample. Category 1 will include wetlands that are either natural in origin or have been created for the purpose of increasing and/or replacing wetland habitat (e.g., compensatory mitigation wetlands). Wetlands in this category are clearly waters of the state (State of Minnesota 2007). Category 2 will be assigned to

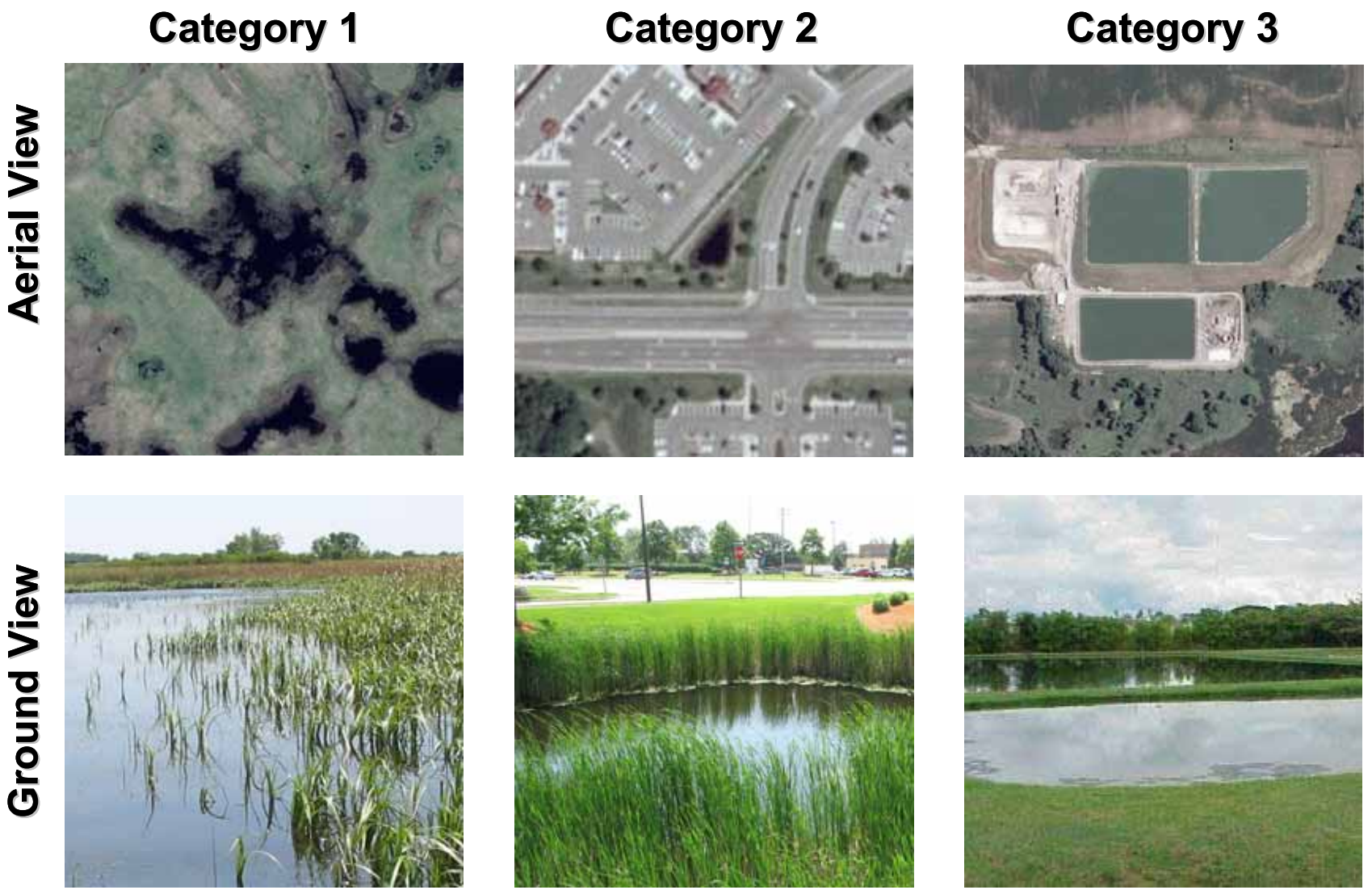

Figure 4. Examples from each category used in the post-stratification of the phase 2 sample.

waterbodies that have either been created or physically altered specifically for treatment, commercial, agricultural, or recreational purposes. Waterbodies within this category may or may not be considered waters of the state. Category 3 waterbodies are those that are clearly not waters of the state and are thus considered non-target in the depressional wetland survey. This category will be assigned to waterbodies that have been created or altered for the purposes listed under category 2, but also have an artificial hydrology maintained by pumping and/or are lined with geo-textile fabrics, concrete or other such impermeable layers. A more detailed description of the categories, including the criteria being used to make categorizations, examples, and the subsequent action related to each category, is outlined in Appendix A. An example from each category is also provided in Figure 4.

Statistical Analyses

The probabilistic survey described above is designed to estimate depressional wetland condition statewide and for individual ecoregions. Cumulative distribution functions will be the primary method to produce these estimates by summarizing the extent of the population at or below any given level of a response variable (e.g., IBI, MnRAM function, water chemistry parameters). The design of this survey allows the extent of the population to be presented as percentages as well as the associated number of depressional wetland basins or depressional wetland area. Where appropriate, interpretation of response variable distributions will be facilitated by the inclusion of performance criteria. For instance, thresholds based on regional reference condition could be used in conjunction with the IBI distributions to estimate the percentage of the population that has deviated from reference conditions. All estimation procedures will account for the unequal probability selection (i.e., weighting) of the design and be performed using the software package R version 2.5.1 (R Development Core Team 2007) or subsequent versions and R statistical routines developed by the US EPA Environmental Monitoring and Assessment Program.

Acknowledgments

Funding for this project was provided by a US EPA Wetland Demonstration Pilot grant (Federal Assistance # WL-96576801). Assistance developing the design of this wetland quality survey was provided by Tony Olsen. Mary Kentula and Rich Sumner provided comments that helped to shape this design as well as the design of the next wetland quality survey that will include all wetland types.

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Appendix A. Depressional wetland quality survey reporting categories.

Category	Brief Description	7050 Status	Field Evaluation Criteria	Examples	Action
1	Natural Creation/Natural Hydrology **Or** Artificial Creation for Wildlife Habitat and/or Mitigation Credit	Waters of the State	No evidence of major physical alterations[1] within the wetland and does not appear to be a manmade. **Or** Manmade/physically altered wetlands for the purpose of creating/improving wildlife habitat, mitigating the loss of another wetland, or when the purpose can not be perceived.	All unmodified wetlands irrespective of surrounding land use; Bog ponds; Forest ponds; Beaver ponds; Mitigation wetlands; Wildlife ponds; Wildlife Management wetlands/ponds; Natural wetland being used for aquaculture; Abandoned mining ponds (< 2m deep);	Monitor and report wetland condition both combined with as well as without Category 2 wetlands
2	Artificial Creation/Natural Hydrology	Waters of the State / Not Waters of the State	Wetland has undergone major physical alterations[1] or was created specifically for treatment, commercial, agricultural, residential, or recreational purposes. **And** Its hydrology is not artificially controlled and/or manipulated.	Stormwater ponds; Livestock ponds; Aquaculture ponds (w/o liner); Golf course water hazards; Ornamentation ponds; Recreational ponds;	Monitor and report wetland condition combined with Category 1 wetlands; Determine 7050 status of individual waterbodies; If access denied, photograph site if possible
3	Artificial Creation/Artificial Hydrology	Not Waters of the State	Wetland has undergone major physical alterations[1] or was created specifically for treatment, commercial, agricultural, residential, or recreational purposes. **And** Its hydrology is artificially controlled and/or manipulated for purposes other than wildlife management.	Municipal wastewater stabilization and tertiary treatment ponds; Industrial wastewater treatment ponds; Permitted feedlot treatment ponds[2]; Ponds in an active quarry; Swimming ponds; Cranberry impoundments; Aquaculture ponds (w/ liner); Wild rice paddies[3]; Drinking water polishing ponds; Other permitted treatment works	Do not sample; Photograph if possible; Assign 'AF' water regime to polygon(s) in wetland quantity geodatabase

[1] Descriptions of major physical alterations included in 'Minnesota Water Quality Standards: Physical Alterations to Wetlands', Water Quality/Surface Water Fact Sheet #6.01, March 2005 (http://www.pca.state.mn.us/publications/wq-s6-01.pdf)

[2] See 'Options for Handling Feedlot Runoff at Large CAFOs', Water Quality/Feedlots Fact Sheet #6.57, August 2006 for additional information on types of permitted treatment systems. (http://www.pca.state.mn.us/publications/wq-f6-57.pdf)

[3] There are an estimated 25,000 acres of wild rice paddies in Minnesota (source: http://www.savewildrice.org)